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Prediction of Gas Consumption in Transportation Based on Grey System Theory

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Abstract—*Prediction of gasoline consumption in transportation accurately has important reference value for the scientific planning and decision making on the energy needs and environmental protection. For the lack of historical data of gasoline consumption in transportation, a grey gas consumption prediction model is built based on grey system modeling and the analysis of degree of grey incidence and residual. Contrastive analysis of specific value of the variance and small error probability of a case study with accuracy grades indicated that the gray gas consumption prediction model is fitting precisely and reliable.*

Keywords—gasoline consumption, grey system theory, prediction model, transportation.

I. INTRODUCTION

The large number of consumption of gas in transportation is an important factor that leads to the intension of resource requirement. In addition, the gas combustion produces CO2, which is the main greenhouse gas, and other resultants CO, UHC(unburned hydrocarbon) and NOx, which do harm to human health and the environment[1]. Therefore, prediction of gas consumption in transportation in future can provide a high reference value for the scientific planning and decision making on the energy needs and environmental protection.

In data prediction, Alex D. Papalexopoulos et al. proposed regression prediction model, which was built for mathematical analysis based on the historical data, and then for prediction. The independent variable of the model could be one or more, according to the number of independent variables, the model was divided into monadic or multivariate regression model [2].Ibrahim Moghram et al. proposed time sequence forecasting method, which assumed that the sequence was generated by a random process first, then built a model, which described the process, based on the historical data and estimated the parameters, finally predicted the data [3]. Artificial neural network had strong learning and nonlinear mapping ability. Training the network with the historical data until its performance met the desired error range, and then it could be used for data prediction [4].

In transportation field, the annual gas consumption, which is affected by the climate, economy, vehicle types and other factors, presents a nonlinear time sequence within a certain time range. What's more, it is difficult to get gas consumption figures, so there is little historical data. In this paper, for the characteristics of the transportation gas consumption statistical data, the transportation gas consumption prediction model based on grey theory is established, and is used for the prediction of gas consumption in transportation.

II. GREY SYSTEM THEORY

The grey system theory was created by Deng Julong, who works on unascertained systems with partially known and partially unknown information by drawing out valuable information by generating and developing the partially known information[5]. For the grey prediction method, firstly, it needs data mining and processing; secondly, the grey sequence is generated, which can weaken the randomness of the original data and indicate the trends; thirdly, the grey sequence is fitted, which increases in indices, with differential equation; finally, the dynamic predition model is build and the future data can be predicted[6].

Grey prediction model is GM(n,h) in general, which means n-order grey differential equations with h variables. The GM(1,1) model is one of the most frequently used grey prediction model[7-11], which changes the exponential model into differential equation, and decreases the error with initial condition.

III. GAS CONSUMPTION PREDICTION MODEL

The annual gas consumption data

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \cdots x^{(0)}(k) \cdots, x^{(0)}(n)\}$$

can be listed as the original sequence, where

$$x^{(0)}(k) \geq 0, k = 1,2,\cdots, n.$$

With 1-AGO (Accumulating generation operator), the gas consumption accumulating sequence is

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n)\}$$

where

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$$x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i)\cdot$$

Accumulating generation operator is a kind of method which can find the integration features from the original sequence.

With the gas consumption accumulating sequence, the mean generation with consecutive neighbors is

$Z^{(1)}=\{Z^{(1)}(2),Z^{(1)}(3),\cdots,Z^{(1)}(N)\}$,

where $Z^{(1)}(k)=0.5x^{(1)}(k-1)+0.5x^{(1)}(k), k=2,3,\cdots n$.

By the mean generation with consecutive neighbors, the 'holes', which is the vacancies of the sequence, can be efficiently filled.

For Model GM(1,1), the grey differential equation can be expressed as Eq. 1.

$$x^{(0)}(k)+aZ^{(1)}(k)=b \quad (1)$$

The value of a and b can be obtained by least-squares estimation shown in Eq. 2.

$$\hat{a}=(a,b)^T=(B^TB)^{-1}B^TY \quad (2)$$

where $B=\begin{bmatrix}-Z^{(1)}(2) & 1\\ -Z^{(1)}(3) & 1\\ \vdots & \vdots\\ -Z^{(1)}(n) & 1\end{bmatrix}$, $Y=\begin{bmatrix}x^{(0)}(2)\\ x^{(0)}(3)\\ \vdots\\ x^{(0)}(n)\end{bmatrix}$.

For the Eq. 1, which is a grey differential equation, its solution is shown in Eq. 3, which makes the grey equation white.

$$\hat{x}^{(1)}(k)=(x^{(1)}(1)-\frac{b}{a})e^{-ak}+\frac{b}{a} \quad (3)$$

Let $x^{(1)}(1)=x^{(0)}(1)$, Eq. (3) can be expressed as Eq. 4.

$$\hat{x}^{(1)}(k+1)=(x^{(0)}(1)-\frac{b}{a})e^{-ak}+\frac{b}{a}, k=1,2,\cdots,n \quad (4)$$

With $\hat{x}^{(1)}(k+1)=\hat{x}^{(1)}(k)+\hat{x}^{(0)}(k+1)$, the prediction value of $x^{(0)}(k+1)$ is shown in Eq. 5.

$$\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k)=(1-e^{a})(x^{(0)}(1)-\frac{b}{a})e^{-ak} \quad (5)$$

IV. ACCURACY TEST OF THE MODEL

Accuracy test is to calculate the relative error of original sequence and gey sequence. When the error is within an acceptable range, the model can be used for prediction. The mean value and the variance of original sequence are shown in Eq.6 and Eq. 7.

$$\bar{x}=\frac{1}{n}\sum_{k=1}^{n}x_k^{(0)} \quad (6)$$

$$X_1^2=\frac{1}{n}\sum_{k=1}^{n}(x_i^{(0)}-\bar{x})^2 \quad (7)$$

The residual sequence is

$\varepsilon^{(0)}=(\varepsilon(1),\varepsilon(2),\cdots,\varepsilon(n))$,

where $\varepsilon(k)=x^{(0)}(k)-\hat{x}^{(0)}(k), k=1,2,\cdots,n$.

The relative error sequence is

$$\Delta=\left(\left|\frac{\varepsilon(1)}{x^{(0)}(1)}\right|,\left|\frac{\varepsilon(2)}{x^{(0)}(2)}\right|,\cdots,\left|\frac{\varepsilon(n)}{x^{(0)}(n)}\right|\right)=\{\Delta_k\}_1^n,$$

then the mean value and the variance of residual sequence are shown in Eq.8 and Eq. 9.

$$\bar{\varepsilon}=\frac{1}{n}\sum_{k=1}^{n}\varepsilon_k^{(0)} \quad (8)$$

$$X_2^2=\frac{1}{n}\sum_{k=1}^{n}(\varepsilon_i^{(0)}-\bar{\varepsilon})^2 \quad (9)$$

The grey prediction model can be tested by the following two test indicators:

(1) SVV (specific value of the variance)

$$C=X_2/X_1 \quad (10)$$

(2) SEP (Small error probability)

$$p=P(|\varepsilon(k)-\bar{\varepsilon}|<0.6745X_1) \quad (11)$$

The detailed prediction accuracy grades[12] are shown in table 1.

Table.1:Table of accuracy grades

Accuracy grades of prediction	p	C
Very satisfied	>0.95	<0.35
Satisfied	>0.80	<0.5
A little satisfied	>0.70	<0.65
Dissatisfied	≤0.70	≥0.65

V. A CASE STUDY

Annual transportation gas consumption of one country from 2003 to 2007 is shown in Table 2.

Table.2:Annual transportation gas consumption

Year	Gas consumption [gallon]
2003	12417
2004	13380
2005	13284.2
2006	13019.4
2007	12998.8

Take the annual transportation gas consumption of one country from 2003 to 2007 as original sequence

$$X^{(1)}=\{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(5)\}= \{12417,\ 25797,\ 39081.2,\ 52100.6,\ 65099.4\} \quad (12)$$

After 1-AGO, the accumulating sequence is

$$X^{(1)}=\{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(5)\}= \{12417,\ 25797,\ 39081.2,\ 52100.6,\ 65099.4\} \quad (13)$$

With the mean generation,

$$Z^{(1)} = \{Z^{(1)}(2), Z^{(1)}(3), \cdots, Z^{(1)}(5)\} = \{19107,\ 32439.1,\ 45590.9,\ 58600\}$$

and with Eq. 2, the solution of $\hat{a}$ is

$$\hat{a} = (a,b)^T = (B^T B)^{-1} B^T Y = \begin{bmatrix} 0.0107 \\ 13587.40722 \end{bmatrix} \tag{14}$$

And the whitenization equation is

$$\hat{x}^{(1)}(k+1) = (x^{(1)}(0) - \frac{b}{a})e^{-ak} + \frac{b}{a} = -1256.792e^{-0.0107k} + 1269209.07 \tag{15}$$

With the Eq. 14, the original sequence, the grey sequence, the residual sequence and the relative error are shown in Table 3.

Table.3:Contrastive analysis of original sequence and grey sequence

k	$x^{(0)}(k)$	$\hat{x}^{(0)}(k)$	$\varepsilon(k)$	Δ_k
1	12417	12417	0	0
2	13380	13382.7	-2.72	0.02%
3	13284.2	13240.2	43.99	0.33%
4	13019.4	13099.2	-79.83	0.61%
5	12998.8	12959.7	39.06	0.30%
6		12821.7		

The mean value and the variance the original sequence are shown in Eq.16 and Eq. 17.

$$\bar{x} = \frac{1}{n}\sum_{k=1}^{n} x_k^{(0)} = 13019.88 \tag{16}$$

$$X_1 = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(x_i^{(0)} - \bar{x})^2} = 335.70 \tag{17}$$

The mean value and the variance of residual sequence are shown in Eq.18 and Eq. 19.

$$\bar{\varepsilon} = \frac{1}{n}\sum_{k=1}^{n} \varepsilon_k^{(0)} = 0.1 \tag{18}$$

$$X_2 = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(\varepsilon_i^{(0)} - \bar{\varepsilon})^2} = 44.36 \tag{19}$$

The SVV and the SEP are shown in Eq.20 and Eq. 21.

$$C = X_2 / X_1 = 0.13 < 0.35 \tag{20}$$

$$p = P(|\varepsilon(k) - \bar{\varepsilon}| < 0.6745X_1) = 1 > 0.95 \tag{21}$$

It is known that the established gas consumption prediction model is good from comparing SVV and SEP with Table 1, and it can be used for prediction. The prediction result of gas consumption in 2008 (k=6) is shown in table3.

VI. CONCLUSIONS

The large number of consumption of gas in transportation is an important factor that leads to the intension of resource requirement. In addition, the gas combustion produces do harm to human health and the environment. Prediction of gas consumption in transportation in future can provide a high reference value for the scientific planning and decision making on the energy needs and environmental protection.

The transportation gas consumption prediction model is established based on grey system theory. Contrastive analysis of results with accuracy grades indicated that the gray gas consumption prediction model was fitting precisely and reliable, and can help for the scientific planning and decision making on the energy needs.

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